A Continuous Measurement System of G/T for Satellite Broadcasting Receivers

Yuliman PURWANTO, Yasutaka OGAWA, Kiyohiko ITOH
Faculty of Engineering, Hokkaido University, Saporo 060, JAPAN

1. Introduction

It is well known that rain and snow directly affect the performance of receiving antennas. The performance of satellite broadcasting receivers is determined by a parameter G/T (G = antenna gain, T = equivalent noise temperature at the output port (K)), which is commonly called the *figure of merit.* Since the weather condition always changes, it is important to obtain the G/T values continuously to examine the effect of the weather to the satellite broadcasting receivers. Moreover, the study needs to investigate the performance of various types of antennas simultaneously. Therefore, a continuous measurement system of the G/T values for several satellite broadcasting receivers for a long period is absolutely needed.

The conventional method of G/T measurement cannot perform a continuous measurement because the receiving antenna under test must be oriented in a specified direction (to the zenith) to measure the antenna noise [1],[2]. If the antenna cannot be moved, we must measure the antenna noise at a satellite eclipse period. To solve the noise measurement problem, we propose a *noise estimation* method. Using this method, a continuous measurement of G/T can be performed, and we can measure more than one receiving system almost simultaneously.

2. Measurement Principle[3],[4]

Block diagram of continuous measurement method of G/T developed in Hokkaido University is shown in Fig. 1. The system is based on the *Direct G/T Measurement Method* and *Reference Signal Simultaneous Display Method* [2]. In Fig. 1, the reference signal simultaneous display circuit is called a MEASUREMENT UNIT. The G/T equation can be written as :[4]

$$\frac{G}{T} = \left(\frac{G'_S}{T_o(E_N+1)-T_c}\right)\left(\frac{P}{P_S}\right)\left(\frac{N_E-N_O}{N}\right) \tag{1}$$

where G'_S = effective gain of the standard antenna, T_o = 290 K, E_N = excess noise ratio, T_c = room temperature surrounding the standard noise source (K), P = received power level from the antenna under test (W), P_S = received power level from the standard antenna (W), N_E = noise power when the power supply to the noise source is switched on (W), N_O = noise power when the power supply to the noise source is switched off (W), and N = noise power in the satellite broadcasting channel (W).

The known parameters in Eq. (1) are G'_S, T_o and E_N, and the other parameters must be measured. The measuring signals (P_S or P) and reference signal (P_{REF}) are displayed simultaneously in a spectrum analyzer as two continuous waves (CW), and then the ratios P_S/P_{REF} and P/P_{REF} are measured[2]. Then, we can obtain $(P/P_{REF})/(P_S/P_{REF}) = P/P_S$. Fig. 1b shows the displayed spectrum of these CW signals. The whole measurement steps and parameter calculations are controlled by a computer (HP-9816). The other computer is used as an auxiliary one to measure temperatures, wind-speed and wind-direction. The satellite signal of BS channel-7 is used for the measurement.

It is desired to use a standard gain horn antenna as the standard antenna. However, such a horn antenna has a low gain due to the small aperture so that the receiving power signal from the satellite is very low. In our measurement system, a regular high gain satellite broadcasting receiving antenna is used for the standard gain antenna. Furthermore, to avoid weather effects, the standard antenna is placed at the inside of a room. Consequently, the power flux density at the inside of the room is different from that at the outside where the antennas under test are placed. Employing the effective gain G'_S, we can take the difference into account. In our experiment, we use a 1 meter diameter offset parabolic reflector antenna whose effective gain G'_S = 27.2 dB.

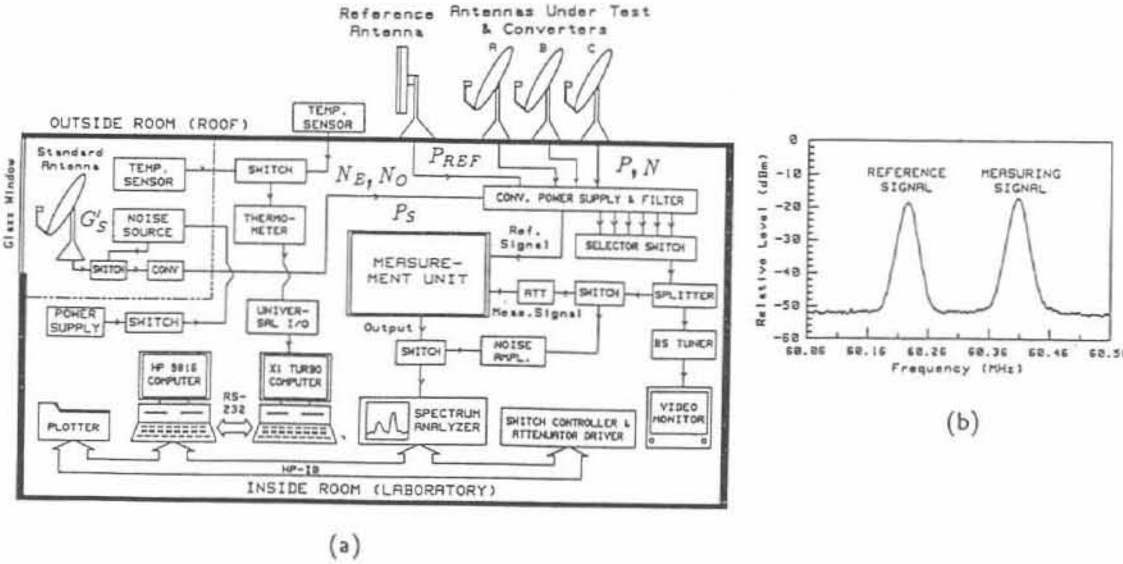

Fig. 1: (a) Block diagram of a continuous G/T measurement system in Hokkaido University, (b) Display of reference and measuring signals.

3. Noise Estimation

An experimental result of noise measurement in the satellite broadcasting band is shown in Fig. 2a. This figure shows noise power spectrum characteristics in the first IF band which are measured during a satellite eclipse. It can be seen that in the satellite broadcasting band the noise spectrum distribution decreases gradually with respect to frequency. Therefore, the noise power in the satellite broadcasting channel can be interpolated from the noise power level at the outside of the channel. Then, the noise power level in the satellite broadcasting channel can be obtained *continuously* even when the satellite radiates the signal.

The frequency points at which the estimation of noise power is performed should be determined far enough from the satellite broadcasting signal and must not be interfered by the signal spectrum of adjacent channel. Considering these reasons, the center frequency points in the guard bands will be the best choice. Fig. 2b shows these frequency points (f_L and f_H). Let the noise power levels at f_L and f_H be N_L and N_H, then the noise power in the satellite broadcasting channel is estimated as : $N = \frac{N_L+N_H}{2}$. To obtain accurate noise estimation data, each of f_L and f_H is not actually a single frequency point, but we have frequency bands of 100 KHz so that N_L and N_H are average values in those bands. These bandwidths can be expanded until 1 MHz or more (restricted by the satellite signal spectrum), but it will affect the sweep-time of the spectrum analyzer. We consider that 100 KHz is a reasonable bandwidth to estimate the noise power.

4. Measurement Results

The estimated noise values were compared with the actual noise in the satellite broadcasting band. Both measurements were performed simultaneously during a satellite eclipse period. The results of these measurements are shown in Fig. 3a, and a histogram of the difference is shown in Fig. 3b. Fig. 3a shows that the measured noise levels (dotted line) and estimated noise levels (solid line) are very close, and Fig. 3b shows that the error of the estimated noise levels are within ± 0.2 dB. We can see from these results that the error of noise estimation affects the G/T measurement only by less than ± 0.2 dB, for the receiving antenna system.

Some experiments of G/T measurement were performed for 3 receiving antenna systems for 24 hours continuously under different weather conditions. The antennas under test are listed in Table 1. The results for clear, rainy and snowy weathers are shown in Fig. 4. Under the clear weather condition, we have steady G/T values (Fig. 4a). When it is raining, the G/T values fluctuate slightly (Fig. 4b). Fig. 4c shows that the G/T values degrade seriously under the snowy weather

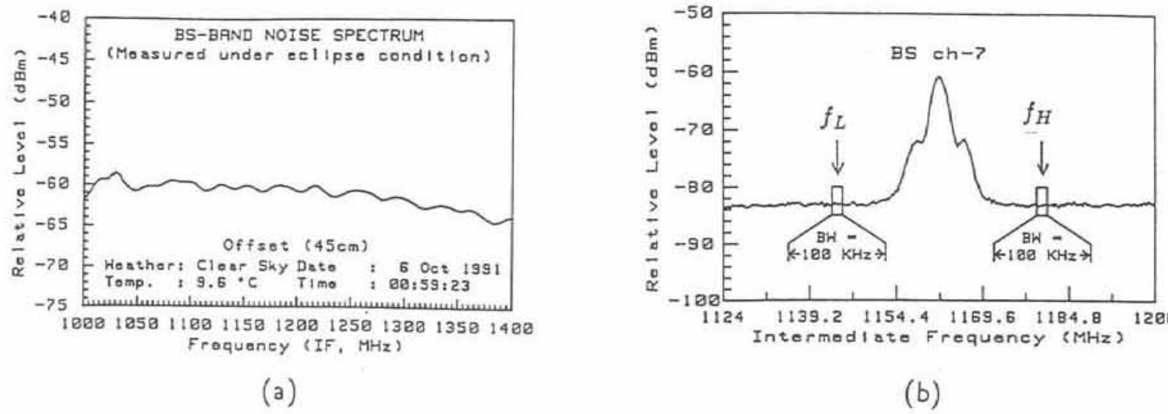

Fig. 2: (a) Experimental measurement result of noise power spectrum in the satellite broadcasting band which is measured in the first IF, (b) Frequency points for noise estimation.

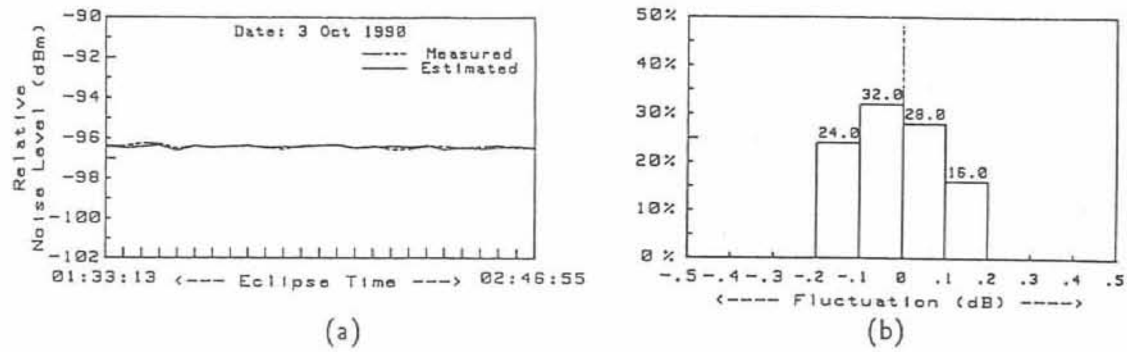

Fig. 3: Comparison of estimated and measured noise power levels : (a) Estimated and measured noise power levels, (b) Measurement error histogram.

condition. We have more than 9 dB degradation for Antenna-A and Antenna-B. We can see from these figures that the continuous G/T measurement system presented in this paper can be used for estimating the effect of the weather conditions to the satellite broadcasting receivers.

Average values of the measured G/T results are calculated from the measured values in clear weather (Fig. 4a). Histograms of G/T fluctuation values around the average are shown in Fig. 4d. From the histograms, we can see that more than 99% of deviation from the average value is within 0.3 dB. Namely, it can be said that the precision of the measurement system is within about 0.3 dB. Using the specification of the antennas, the G/T values were calculated and they are shown in Table 1 (*"Estimated"*). The average and fluctuation of the measured G/T values are also shown in Table 1 (*"Measured"*). Both of the estimated and measured values coincide with each other very well. From these results, it is expected that the measurement system has a sufficient accuracy.

5. Conclusions

A method to measure the G/T value of the satellite broadcasting receiving systems continuously has been presented. Noise measurement problem has been overcome by a *noise estimation* method instead of the conventional measurement. Experimental results show that the estimated values and the measured values in the satellite broadcasting band coincide with each other very well. It means that the *noise estimation* method is valid. Using this method, we can perform a continuous G/T measurement. Experimental results of the G/T values for several antennas have been presented. The results show that the measurements are valid. More than one receiving antenna can be measured almost simultaneously so that a comparison of the figure of merit for various types of antennas can be performed. No special site is needed to perform the measurement.

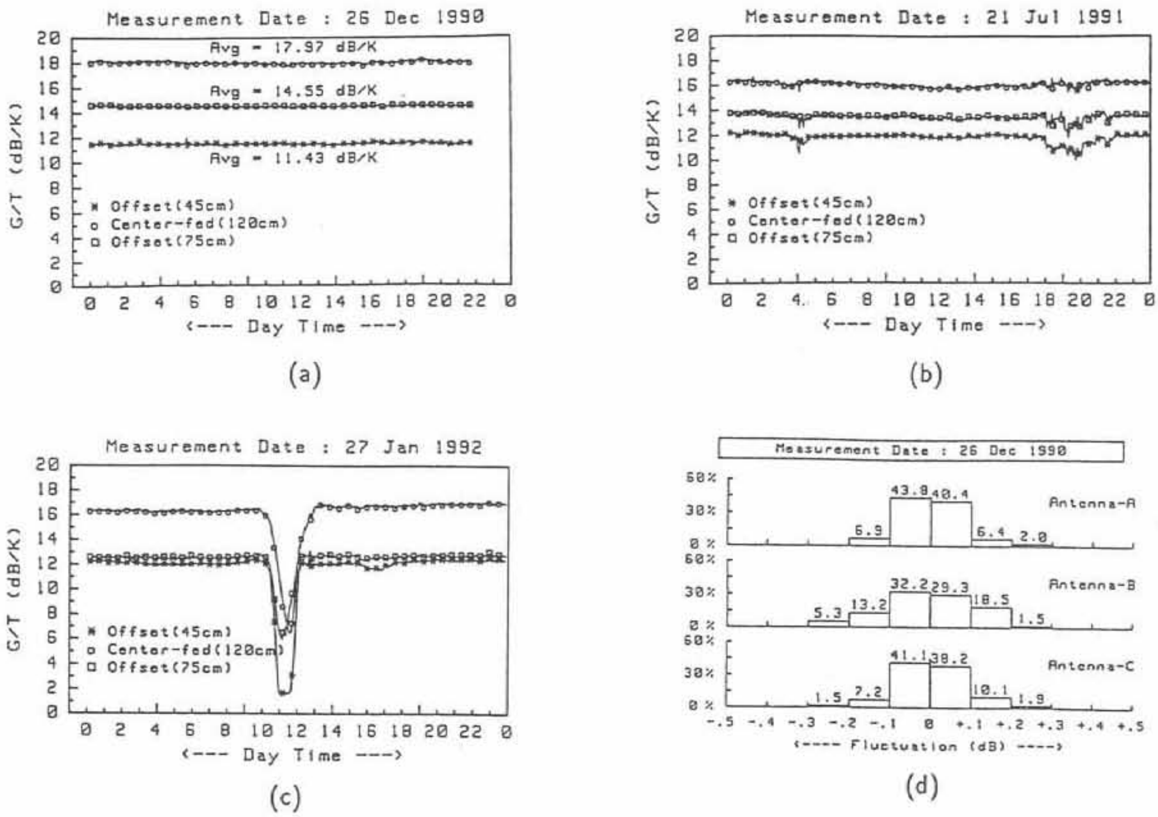

Fig. 4: Examples of G/T measurement results : (a) Clear weather, (b) Rainy weather, (c) Snowy weather, (d) Histogram of measured G/T.

Table 1: Estimated and Measured Results (BS channel-7).

Antenna Type & Data	G/T (dB/K)	
	Estimated	*Measured*
Antenna-A : Offset Parabola $\phi = 45$ cm, $G = 33.8$ dB (Spec.) $NF = 2.0$ dB (typical)	11.33	Average = 11.43 (Fluctuation = ± 0.3)
Antenna-B : Centerfed Parabola $\phi = 120$ cm, $G = 41.7$ dB (Spec.) $NF = 2.5$ dB (typical)	18.16	Average = 17.97 (Fluctuation = ± 0.3)
Antenna-C : Offset Parabola $\phi = 75$ cm, $G = 37.4$ dB (Spec.) $NF = 2.2$ dB (typical)	14.69	Average = 14.55 (Fluctuation = ± 0.3)

Acknowledgement

This work was supported by Grant-in-Aid for Scientific Research 62420033 from the Ministry of Education, Science and Culture of Japan.

References

[1] K. Ohmaru and Y. Mikuni, "Direct G/T Measurement for Satellite Broadcasting Receivers," *IEEE Trans. Broadcasting*, vol.BC-30, No.2, pp.38-43, June 1984.

[2] H. Isono and K. Ohmaru, "Measurement of Antenna Gain and G/T with Satellite Broadcasting Wave," *J. ITEJ*, vol.40, No.3, pp.184-189, Mar. 1986.

[3] Y. Purwanto, M. Ohmiya, Y. Ogawa, and K. Itoh, "Automatic Direct Measurements Method of G/T for Satellite Broadcasting Receivers," *ITEJ Technical Report*, vol.14, No.13, pp.61-66, Feb. 1990.

[4] Y. Purwanto, Y. Ogawa, and K. Itoh, "Development of a Continuous Measurement System of G/T for Satellite Broadcasting Receivers," *Paper of Technical Group, TGA·P91-126, TGSAT91-120, IEICE*, pp.45-51, Feb. 1992.